Network Troubleshooting

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6 Cable Infrastructures in Local-Area Networks

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Section II
Troubleshooting Local-Area Networks

Cable Infrastructures in Local-Area Networks

6

"Always expect the worst and you will never be disappointed."

PETER WASTHOLM

The main prerequisite for trouble-free operation of a local-area network is the use of a high-quality cable infrastructure with specified data transmission parameters. Estimating the overall transmission characteristics of network cable infrastructures is an extremely complicated task. In practice, the only way to design a physical foundation for reliable data communications is through strict adherence to accepted standards for the cabling. The ISO/IEC IS 11801 specification, from which the European standard EN 50173 is derived, is an internationally recognized standard that describes customer premises cabling. The corresponding North American standard is the EIA/TIA 568A Commercial Building Telecommunications and Wiring Standard.

The ISO/IEC IS 11801 specification distinguishes between three types of cable by range: campus backbone, for use over distances of up to 1,500 meters; vertical backbone, for up to 500 meters; and horizontal cabling, for connecting components on the same floor over distances of up to 90 meters. ISO/IEC IS 11801 also

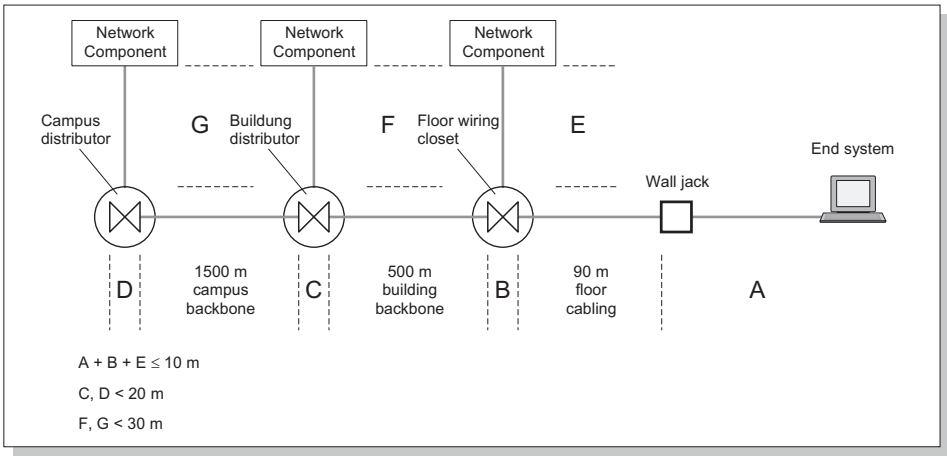

Figure 6.1 Campus, vertical and horizontal cabling according to ISO/IEC IS 11801

defines the maximum permissible lengths for cabling systems, as well as the upper limits for work area and device cabling (see Figure 6.1).

The transmission media described in the cable performance categories are twisted copper wire and single-mode and multimode fiber-optic cabling. Coaxial cable, or coax, is used in 10Base2 and 10Base5 networks, but is not suitable for structured cabling and thus not in the specifications mentioned previously. The only standard that defines coaxial cabling is EIA/TIA 568, which describes 50 Ω coax as an option for horizontal cabling.

The different types of twisted-pair data cable available are divided into seven performance categories, numbered 1 through 7. Twisted-pair cabling can be used over various distances in any of the six ISO/IEC application classes (A through F) defined for copper cabling, depending on the transmission characteristics of each category. A seventh application class has been defined for the use of optical transmission media. Bandwidth ranges and typical applications are also defined for each class. Class A applications, for example, require bandwidths of up to 100 kHz; this class includes such applications as X.21/V.11 and ISDN S_0. Class F applications can require up to 600 MHz bandwidth, and include Gigabit Ethernet and 622 Mbit/s ATM (see Figure 6.2).

Application classes per ISO/IEC IS 11801	Definition
Class A	Applications up to 100 kHz (analog telephony, X.21, ISDN S_0, etc.)
Class B	Applications with bandwidths of up to 1 MHz (X.21, ISDN S_0)
Class C	Applications with bandwidths of up to 16 MHz (ISDN S_{2M}, 10Base-T, 4/16 Mbit/s Token Ring)
Class D	Applications with bandwidths of up to 100 MHz (100Base-TX, ATM 155 Mbit/s, Gigabit Ethernet)
Class E	Applications with bandwidths of up to 200 MHz (ATM 155 Mbit/s, Gigabit Ethernet)
Class F	Applications with bandwidths of up to 600 MHz (ATM 155 Mbit/s, Gigabit Ethernet)
Optical data transmission	Data communications over multimode and single-mode optical fiber

Figure 6.2 Application classes for structured cabling per ISO/IEC IS 11801

6.1 Coaxial Cable

6.1.1 Coaxial Cable: Specification and Implementation

Coaxial cable has a copper inner conductor at the center and an outer conductor that acts as shielding. Between the two conductors is an insulator, and the whole is encased in a plastic jacket. Called "coax" (two syllables) for short, coaxial cable can provide data speeds of several gigabits per second and is used for both digital data and television signals.

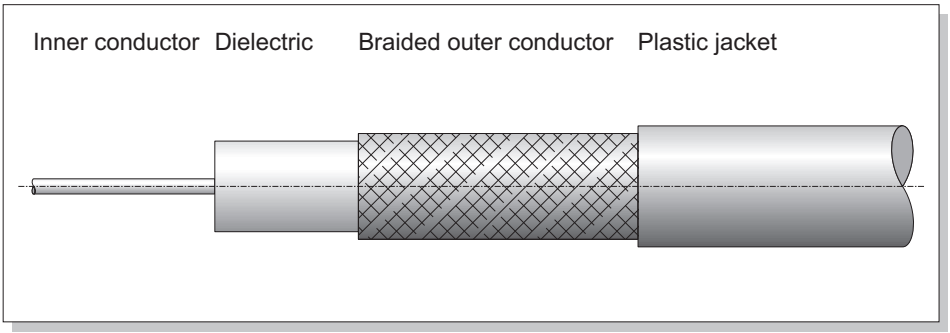

Figure 6.3 Structure of coaxial cable

The types of coax most commonly used for data communications, besides the traditional 50 Ω cable of 10Base2 and 10Base5 Ethernet networks, are RG-62 coaxial cable, which has an impedance of 93 Ω (used to connect IBM 3270 terminals), RG-6 and RG-11 coax, with 75 Ω impedance, and twin-axial cable, with an impedance of 105 Ω (AS/400, IBM /36 /38 series). Detailed specifications for the various types of cable are found in the MIL-C-17G standard (see Figure 6.4).

There are two ways to connect network components to coaxial cable in bus-based Ethernet networks (10Base2, 10Base5). The first method consists of cutting the cable and inserting a T-connector. The second method involves drilling a hole in the coaxial cable until the inner conductor is just reached, and then inserting a special connector known as a tap or vampire tap. This method is used with 10Base5 cabling ("yellow cable" or "thick Ethernet"), while T-connectors are commonly used in 10Base2 networks ("thin Ethernet" or "cheapernet").

The advantage of vampire taps is that new components can be installed without interrupting network operation. This can be an important factor, especially in

Cable designation	RG-58 10Base2 cable, thin Ethernet, Cheapernet	RG-8A/U 10Base5 cable, thick Ethernet, yellow cable
Use	10Base2	10Base5
Impedance (Ω)	50	50 ± 2
Attenuation (dB/100 m)	4.6 at 10 MHz	1.7 at 10 MHz
Velocity factor	0.77	0.83 – 0.86
Inner conductor (mm)	0.94	2.7
Insulation (mm)	2.52	6.15
PVC outer jacket (mm)	4.62	10.3
Bending radius (cm)	5	25

Figure 6.4 Specifications for RG-58 and RG-8A/U coaxial cable (10Base2 and 10Base5)

production networks. Care must be taken in using this method, however, as the cable may break if the hole is drilled too deep. If the hole is not deep enough, the connection will be unstable. In either case, serious network problems can result.

10Base5 cable is usually equipped with N-type connectors; 10Base2 cable with BNC connectors. To prevent reflections, each cable end must be connected to a 50 Ω terminating resistor. It is essential that one of the terminating resistors be grounded, and equally important that the second one *not* be grounded. If neither terminating resistor is grounded this could result in an electrical charge throughout the entire network. If both are grounded and the two grounds have different electrical potentials, considerable current on the line may result.

In addition to observing segment length limitations (185 meters for 10Base2; 500 meters for 10Base5), it is especially important to respect the minimum bending radius for coaxial cable (5 cm for 10Base2; 25 cm for 10Base5) and to install pressure relief fixtures over the cables where necessary to prevent damage caused by equipment housings, other objects resting on the cables or other mechanical stress.

	10Base2	10Base5
Maximum segment length	185 m	500 m
Maximum bending radius	5 cm	25 cm
Maximum number of nodes per segment	30	100
Maximum attenuation per segment	8.5 dB	8.5 dB
Maximum transmission delay per segment	950 ns	2,165 ns

Figure 6.5 Design guidelines for 10Base2 and 10Base5 networks (IEEE 802.3)

6.1.2 Troubleshooting Coaxial Cable (10Base2, 10Base5)

The first steps in tracking down the source of a problem in coaxial cable include checking the voltage, resistance, terminating resistors, noise, cable lengths, reflections and attenuation. When these tests are performed conscientiously, they often lead directly to the cause of the problem.

6.1.2.1 Measuring the Voltage in Network Cabling

The easiest way to measure the voltage in a segment of network cabling is to use a voltmeter on an unused T-connector or vampire tap. If the voltage is less than ±100 mV (±200 mV at one end of the cable), then there is probably nothing wrong in this area. If the voltage exceeds 100 mV—especially if the reading is several volts—then it is likely that the supply voltage of a media access unit (MAU) or other component on the cable segment is leaking into the network cable. In this case, disconnect the MAUs one at a time and repeat the voltage measurements after each unit is removed. Because more than one MAU may be defective, do not re-connect the deactivated units to the network until the source of the problem has been isolated. If the voltage is still too high even after all components have been disconnected, the cable is probably grounded in more than one place, with different electrical potentials at each ground. Remove all grounds except one. Sometimes a second ground is created by a defective network component that

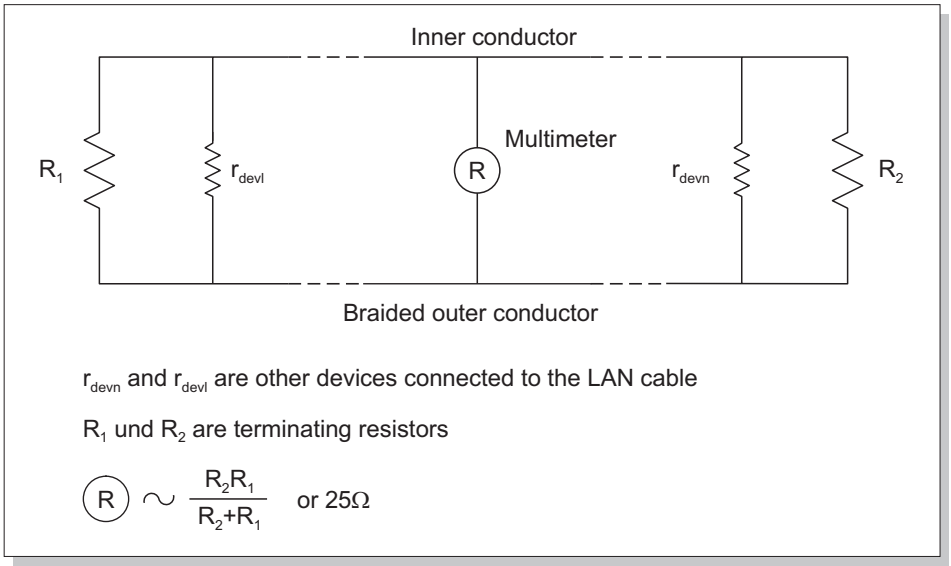

Figure 6.6 Measuring resistance in coaxial cable

does not electrically isolate network components from the data transport medium. If this is the case, a simple network interface card may be the cause of the voltage problem.

6.1.2.2 Measuring the Cable Resistance

All network components must be switched off before performing resistance measurements. Measure resistance at a T-connector or vampire tap (see Figure 6.6, 6.7).

If the values measured are between 24.0 and 26.6Ω for 10Base5 or between 24.4 and 26.6Ω for 10Base2, then the level of resistance in the cable is not the root of the problem.

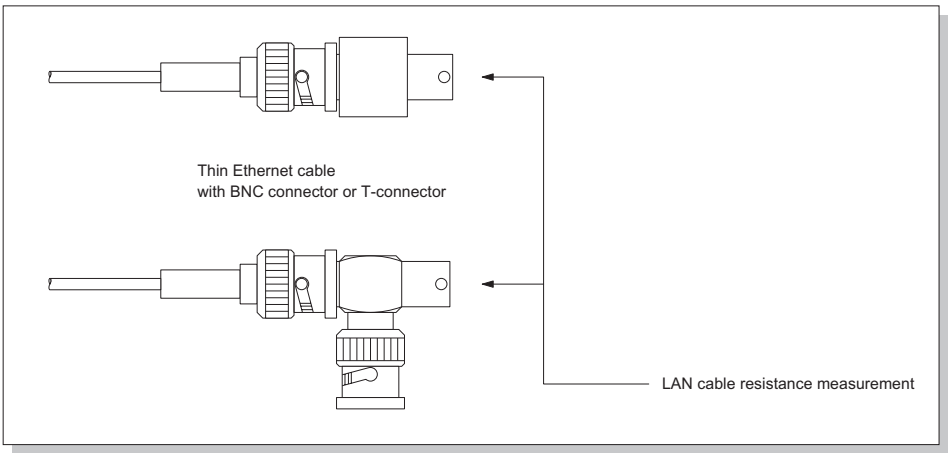

Figure 6.7 Test setup for measuring the resistance of coaxial cable

If the resistance is high, the cable is broken somewhere along its length. In this case, isolate the defective cable segment by repeating the resistance measurements on neighboring T-connectors or vampire taps until you detect normal values.

If the resistance is very low, the cable is short-circuited. You can quickly pinpoint the location of the short using a time-domain reflectometer (TDR).

6.1.2.3 Testing the Terminating Resistor

If you suspect that you have a defective terminating resistor, make sure you test the T-connector and the terminating resistor simultaneously. It is possible that the terminating resistor is in perfect condition, but connected to a defective T-connector (see Figure 6.9).

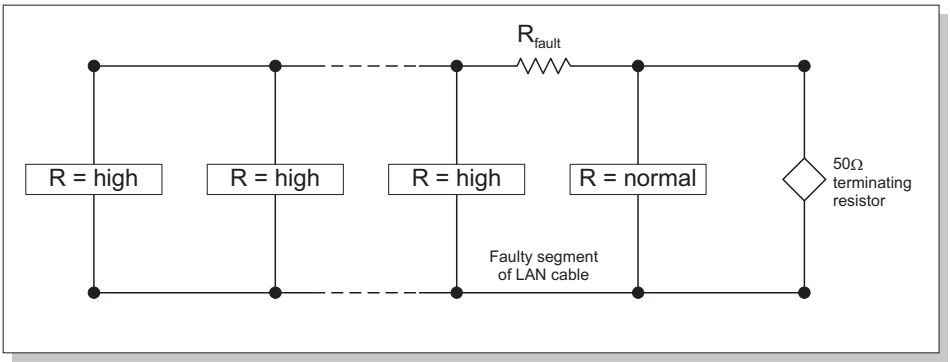

Figure 6.8 Systematic search for defects in coaxial cable

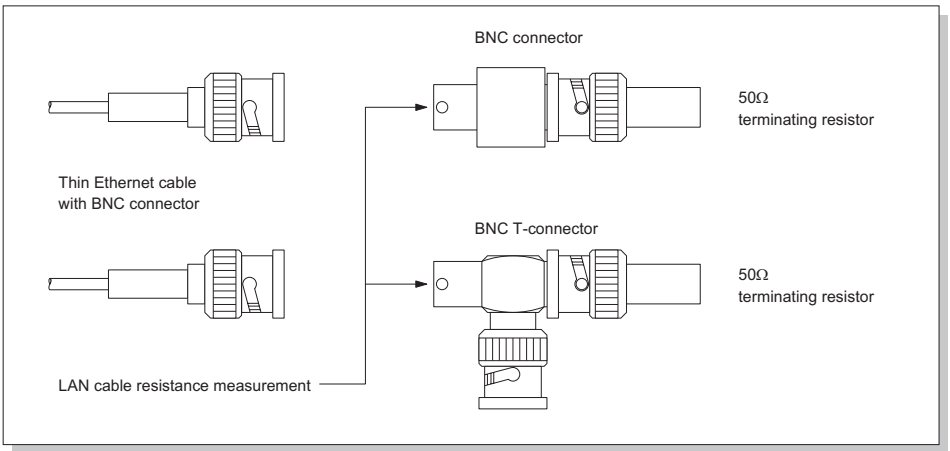

Figure 6.9 Setup for testing a terminating resistor

6.1.2.4 Measuring Electromagnetic Interference

When line noise is measured using a cable scanner or a spectrum analyzer, the frequency of electromagnetic interference in the line can be identified. Noise is measured between the shielding (outer conductor) and the core (inner conductor). If the noise exceeds permissible levels, check the area around the affected cable route for possible sources of interference, including production environments, elevators, photocopiers, fluorescent tubes, arc welding equipment and X-ray devices. If a spectrum analyzer is available you may try to determine the frequency spectrum of the interfering equipment. Typical interference frequency ranges are listed:

Potential source of interference	Operating frequency
FM radio and TV signals	1-100 MHz
GSM telephones	800 MHz
Pagers	500 MHz
PCs	100-400 MHz
Fluorescent tubes, electric motors	10-150 kHz

6.1.2.5 Measuring Cable Lengths, Reflections and Short Circuits

Cable length, reflections and short circuits can be measured using a time-domain reflectometer or TDR. The TDR transmits a signal and then measures the time that elapses until the signal's reflection is received. Any irregularity in a given cable segment will cause reflections of greater or lesser intensity, depending on the magnitude of the irregularity. The TDR can be set to wait either for the largest reflection that occurs or to measure smaller reflections, such as those that amount to only 30 percent of the original signal. The latter method allows you to determine the distance to impedance anomalies along the cable. To determine the overall cable length, remove the far terminating resistor and set the TDR to measure the greatest reflected signal. If the cable is broken at any point along its length, however, the reflection will come from the break, not from the far end. As is the case with most cable measurement procedures, the cable segment to be tested must be taken out of operation completely before performing TDR measurements.

6.1.3 Symptoms and Causes: Coaxial Cable

Symptom: Intermittent Loss of Connection

Cause (1): Poor or no physical connection to the network cable due to a loose BNC connector or a vampire tap that does not reach the inner conductor.

Cause (2): Terminating resistors exceed tolerance limits.

Symptom: Complete Failure of a Segment

Cause (1): Short circuit in the cable (outer conductor touching inner conductor) due to kinks, defective cable, or vampire tap drilled too deep.

Cause (2): Voltage on the network exceeds permissible levels due to defective MAU or lack of grounding.

Symptom: Unusually High Number of Collisions

Cause (1): Strong reflections in the cable, resulting in collisions.
Check to see if terminating resistor is missing, defective or out of tolerance.
Cause (2): Segment may have too many MAUs.
Cause (3): Segment grounded in more than one place.
Cause (4): Maximum cable length exceeded.

Symptom: Intermittent or Frequent Collisions and Fragments

Cause: Electromagnetic interference.
Check whether photocopiers, pagers, elevators or x-ray devices are being used near the cabling.

Symptom: No Connection or Intermittent Loss of Connection After New Installation

Cause (1): High attenuation in newly installed cables; variations in impedance between connectors or in patch panels.
Cause (2): Impedance of new cable is outside tolerance limits; wrong cable type installed.
Check tolerances and specifications of all new components.

Gathering Information; Common Errors

Most problems in cabling infrastructures arise in conjunction with external alterations. Such changes may have been made intentionally or even inadvertently, as can happen during the course of other activities. Specific information about the context of the problem can provide clues to its exact location and possible causes. Questions to ask at this stage include:

- Has anyone connected or disconnected a PC (laptop or desktop) or any other component to or from the network?
- Has anyone installed an interface card in a computer?
- Has anyone stepped on a cable?
- Has any maintenance work been performed in the building recently (by a telephone company or building maintenance personnel, for example)?
- Has anyone (including cleaning personnel) moved any equipment or furniture?

Figure 6.10 lists the most common causes of problems in coaxial cabling infrastructures:

- Cable continuity is interrupted at a T-connector.
- Continuity fault in a connector.
- Connector has a short circuit.
- Cable insulation is damaged (shielding is visible).
- Cable is kinked or bent too tightly.
- Cable is too long.
- Cable is not grounded.
- Cable is grounded in two places.
- Cable segments look similar, but have different impedances.
- Electromagnetic interference (elevators, electric machinery) or mechanical stress (doors, furniture) exists along cable route.
- Impedance in new cabling exceeds tolerance limits, or the wrong cable type has been installed.
- A MAU is defective.
- Newly installed vampire taps act as mini-antennae and induce signals.
- Network voltage exceeds allowable levels due to a defective MAU or lack of grounding.
- New cables with high attenuation have been installed; variations in impedance between connectors or in patch panels.
- Physical connection to the network cable is poor or does not exist due to loose BNC connectors or to vampire taps that do not reach the inner conductor.
- The segment is grounded in more than one place.
- Short circuit in the cable. This can be caused by any of the following: kinks, cable defects, vampire tap drilled too deep, outer conductor touching copper core.
- Terminating resistor is missing or defective.
- Terminating resistors exceed tolerance limits.
- Terminating resistor is missing, defective or not to specification.
- Too many MAUs exist on the segment.
- Voltage induced by electromagnetic interference. Check whether photocopiers, pagers, elevators or x-ray devices are in use near the affected cable route.

Figure 6.10 The most common causes of problems in coaxial cabling infrastructures

6.2 Twisted-Pair Cable

6.2.1 Twisted-Pair Cable: Specification and Implementation

Whereas coaxial cabling is unbalanced because the outer conductor is always at ground potential, twisted pair is balanced cabling because the signals on each wire of a pair have opposite potentials. Twisted-pair cable can have two or four wire pairs, which are twisted together with 6 to 26 rotations per meter of cable. Twisting the conductors together improves the cable's immunity to electromagnetic interference (EMI). Cable with four wires twisted together is also referred to as twisted quad. A distinction is made between shielded twisted pair (STP) and unshielded twisted pair (UTP). STP has braided shielding, metal foil, or a combination of the two wrapped around each wire pair. In addition to blocking external EMI, this shielding also significantly reduces interference emitted by the wire pairs themselves. Metal foil is more effective than braided shielding against high-frequency EMI, while braided shielding is more effective in absorbing low-frequency radiation. In high-performance Category 7 cabling, for example, which is specified to 600 MHz, each pair of wires is wrapped in metal foil. Cable with this type of shielding is also referred to as pairs in metal foil (PIMF). Another cable type, known as screened STP (S/STP), has shielding around each wire pair plus an additional wrapping of braided shielding around all pairs.

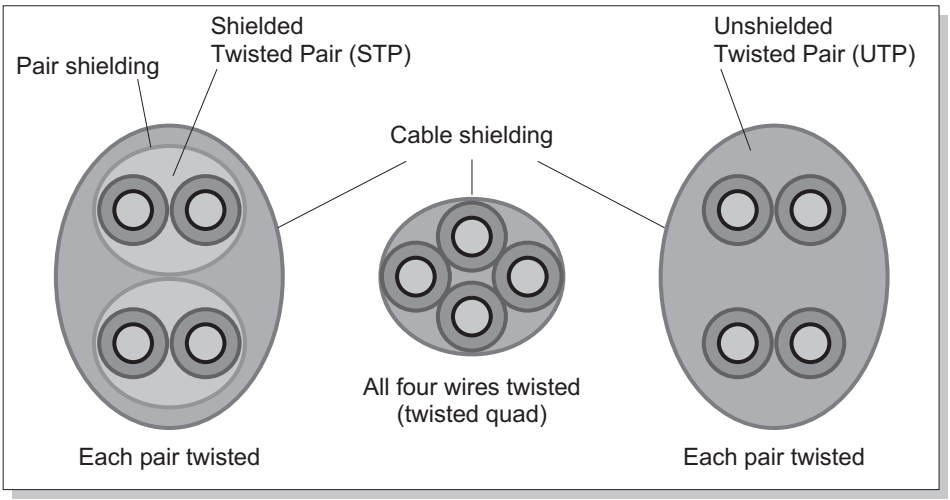

Figure 6.11 Structure of copper twisted-pair cabling

The ISO/IEC IS 11801 standard, divides twisted-pair cabling into seven categories according to frequency ratings. Twisted-pair cabling is specified for frequencies of up to 600 MHz. Figure 6.12 shows the different categories with the maximum distances that they can span.

Cable type	Class A (100 kHz)	Class B (1 MHz)	Class C (16 MHz)	Class D (100 MHz)	Class E (200 MHz)	Class F (600 MHz)	Optical links
Category 3 (symmetrical copper cable)	2 km	500 m	100 m	—	—	—	—
Category 4 (symmetrical copper cable)	3 km	600 m	150 m	—	—	—	—
Category 5 (symmetrical copper cable)	3 km	700 m	160 m	100 m	—	—	—
150Ω (symmetrical copper cable)	3 km	1 km	250 m	150 m	—	—	—
Category 6 (symmetrical copper cable)	—	—	—	—	100 m	—	—
Category 7 (symmetrical copper cable)	—	—	—	—	—	100 m	—
Multimode fiber	—	—	—	—	—	—	2 km
Single-mode fiber	—	—	—	—	—	—	3 km

Figure 6.12 Performance categories for structured cabling according to ISO/IEC IS 11801

The key operating parameters of twisted-pair cabling are the signal propagation speed, attenuation, near-end crosstalk (NEXT) and the attenuation-to-crosstalk ratio (ACR) (see Figure 6.13).

Essential factors for trouble-free network operation include not only the use of high-quality cable of the appropriate category, but also connectors of the right category. When components of different categories are used in the same network, the lowest-performance component on a given transmission path determines the overall transmission characteristics of that path. As with coaxial cable, it is also important to make sure the minimum bending radius allowed for

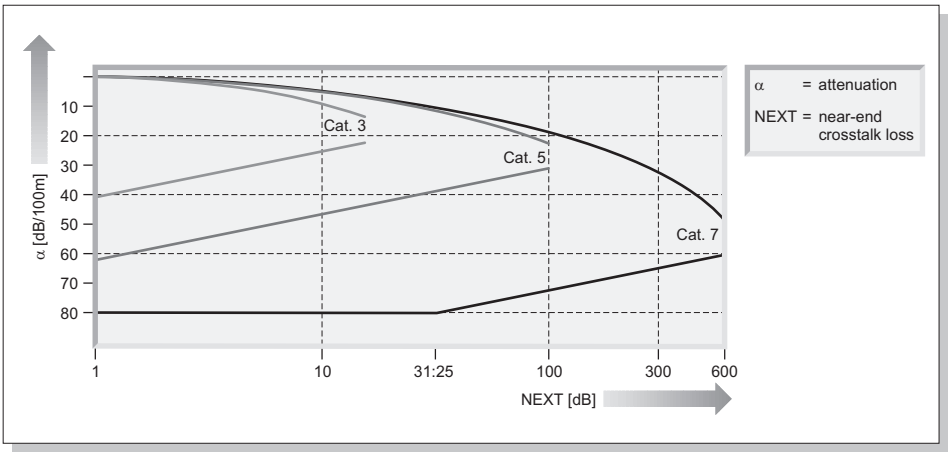

Figure 6.13 Specifications concerning attenuation and NEXT for cabling of Categories 3, 5 and 7

Cable type	Minimum bending radius during installation under tension	Minimum bending radius in installed state	Minimum one-time bending radius
100 Ω, 120 Ω twisted pair	8 times the cable's outside diameter	6 times the cable's outside diameter (in backbones) 4 times the cable's outside diameter (workgroup areas)	N/A
150 Ω twisted pair	N/A	7.5 cm	2 cm

Figure 6.14 Minimum bending radii for twisted-pair cabling (ISO/IEC IS 11801)

the cable is low enough for your installation requirements, and to install protective fixtures where necessary to prevent undue mechanical stress on the cables.

6.2.1.1 Grounding Twisted-Pair Cable Infrastructures

Proper grounding of the cabling infrastructure is absolutely essential. Cable shielding must be grounded both in the patch panel, which should have a ground bus connected to the building ground, and in the wall jack. Connecting cables and patch cables must be grounded in both the wall jack and the end device. It is important that the potential in the wall jack ground is the same as that in the patch panel and terminal device. A simple measurement with a multimeter is

sufficient to determine whether there is a difference in potential between the wall jack shielding and the patch cable shielding. If a noticeable voltage level is detected, the grounding of the individual components must be reviewed so that they all end at the same grounding block. Fiber-optic cabling is used to connect floor wiring closets to the building distributor. This prevents current due to varying ground potentials. This is even more important in connecting building distributors to the campus backbone cable because there can be significant differences in ground potentials from one building to another.

6.2.1.2 Electromagnetic Interference

It is important to make sure that the cable is installed at a sufficient distance from potential sources of electromagnetic interference, especially when using unshielded twisted-pair cables. The North American specification EIA 569 describes the following guidelines for determining appropriate distances:

Source of electromagnetic interference	Minimum distance at line power < 2 kVA	Minimum distance at line power 2 to 5 kVA	Minimum distance at line power > 5 kVA
Unshielded power lines or electrical equipment near open or non-metallic cable ducts	5 in	1 ft	2 ft
Unshielded power lines or electrical equipment near metallic, grounded cable ducts	3 in	6 in	1 ft
Power lines or electrical equipment in grounded metallic shielding near metallic, grounded cable ducts	—	6 in	1 ft
Transformers, electric motors	—	—	3 ft
Flourescent tubes	—	—	1 ft

Figure 6.15 Guidelines for minimum distances between cabling and potential sources of electromagnetic interference (EIA 569)

6.2.2 Troubleshooting Twisted-Pair Cable

The main task in troubleshooting twisted-pair cabling infrastructures is the measurement of key operating parameters, such as cable length, attenuation, NEXT, ACR, and signal-to-noise ratio (SNR). To eliminate the possibility of incorrect pin assignments right at the outset, however, it is a good idea to begin by comparing the pin assignments in the patch panel with those in the corresponding wall jacks. This type of wiring fault can result from incorrect manual wiring, but may also be due to the use of different color-coding systems. The

specifications TIA/EIA 568A and TIA/EIA 568B, for example, define different systems of color-coding for twisted-pair wiring. Figure 6.16 points out typical wiring errors, as well as the color-coding systems used in TIA 568A and in TIA 568B.

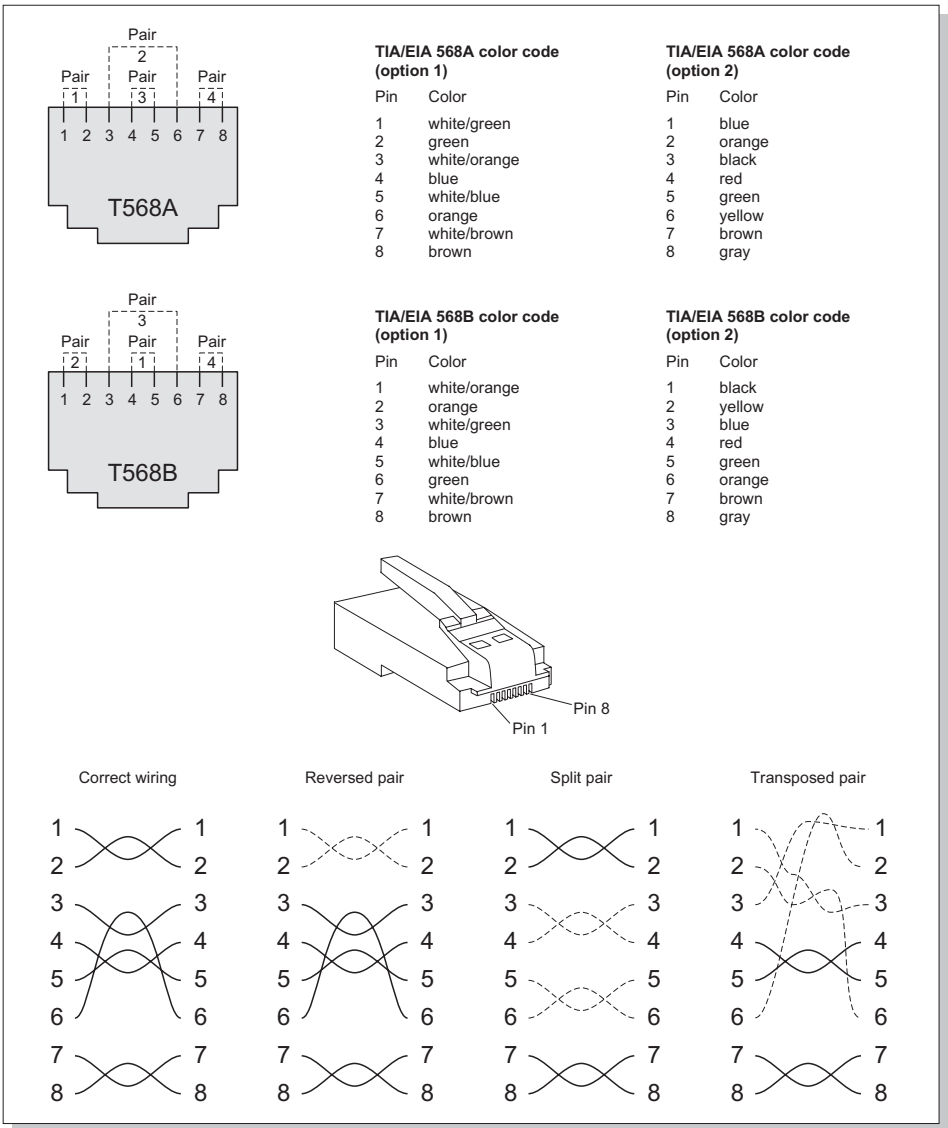

Figure 6.16 Color coding and wiring errors in twisted-pair cabling

To test for faulty pin assignments in the cable, connect the wall plug to a number of different terminating resistors in turn, and test the wire pairs coming from the patch panel with each of the resistors. Reversed pairs are the most common wiring errors and are caused by a simple reversal of the wires, usually at the patch panel. Some wiring errors, such as split pairs, cannot be detected using this procedure. Split pairs can only be detected indirectly, when NEXT tests produce unusually poor results. Split pairs are usually the result of incorrect installation by technicians unfamiliar with twisted pair. Transposed pairs usually result from counting pins from the wrong side of the jack.

Special testing equipment can perform most measurements on twisted-pair cables. Cables are directly connected to a tester using an RJ-45 connector. In some cases, it is also necessary to perform TDR measurements to create a detailed impedance profile for a given length of cable. This requires an oscilloscope, which can easily be connected to a wire pair by means of an RJ-45 breakout box. The pulse for the TDR test can be produced by most cable testing devices. Figure 6.17 shows typical TDR measurement results. Each deviation in

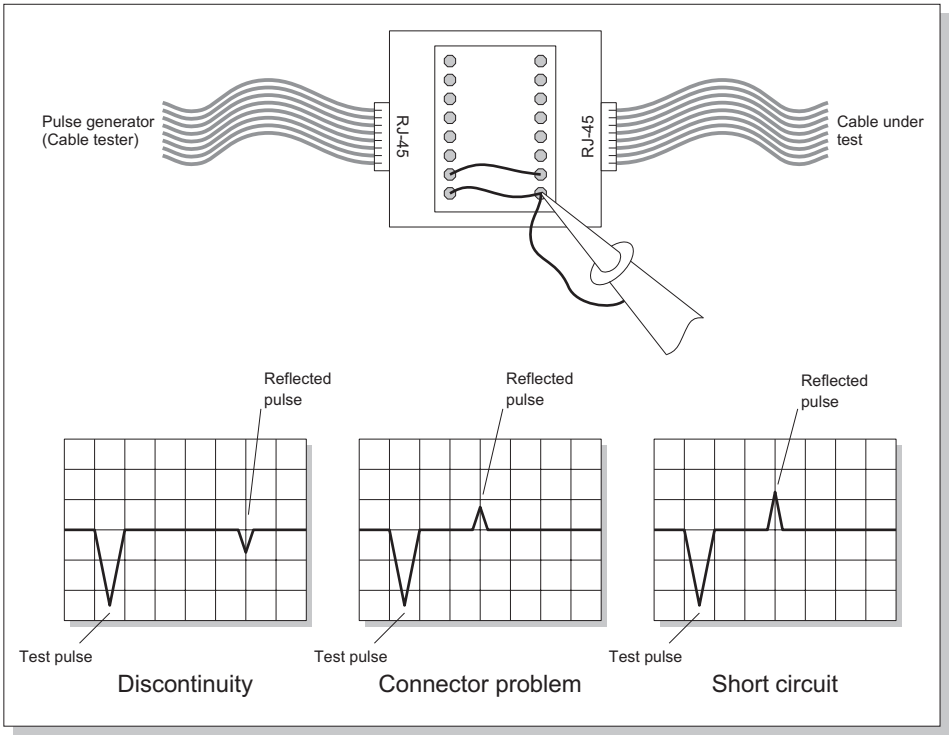

Figure 6.17 TDR measurements on twisted-pair cables

impedance along the cable under test (interruptions, connector problems, short circuits, etc.) causes a reflection of the test pulse. The oscilloscope display shows the type and location of the impedance deviation. Often a number of minor impedance anomalies are detected, none of which would cause a problem on its own, but which are compounded with other errors to cause serious malfunctions.

6.2.3 Symptoms and Causes: Twisted-Pair Cable

Symptom: Diminished Network Performance, Collisions, Frame Check Sequence (FCS) Errors

Cause (1): Crosstalk due to split pairs, untwisted cable segments in patch panels or Token-Ring concentrators.

Cause (2): Crosstalk due to insufficient cable quality for the data speeds used.

Cause (3): Crosstalk and reflections due to unsuitable connector systems (connectors, wall jacks, etc.) for high data speeds.

Cause (4): Electromagnetic interference: cables near photocopiers, power lines, x-ray systems, pagers, production environments or other source of EMI.

Cause (5): Cable and wall plug shielding not grounded or grounded to different potentials.

Symptom: Unusually High Number of Collisions and Fragments

Cause (1): Cable impedance exceeds tolerance limits.
This can be caused by the poor quality of the cable itself or by poor installation (cabling bundled too tightly or bent).

Cause (2): Faulty wiring in patch panel; faulty or loose connectors.

Symptom: Intermittent Loss of Connection or No Connection After New Installation

Cause (1): Excessive attenuation in newly installed cables; variations in impedance between connectors and cables or in patch panels; inadequate wiring through several patch panels.

Cause (2): Wiring faults (reversed pairs, split pairs, transposed pairs).

Cause (3): Patch faults at patch panel.

Symptom: Complete Failure of a Station

Cause (1): Faulty cable; bent cable.

Cause (2): Faulty connection between cable and connector due to defective or low-quality crimp components.

Twisted-pair cable can have either solid or stranded wire. If RJ-45 plugs designed for stranded wire cables (primarily used as patch cables) are used for solid wire, the crimp contacts just touch the surface of the wire and lose contact over time (see Figure 6.18).

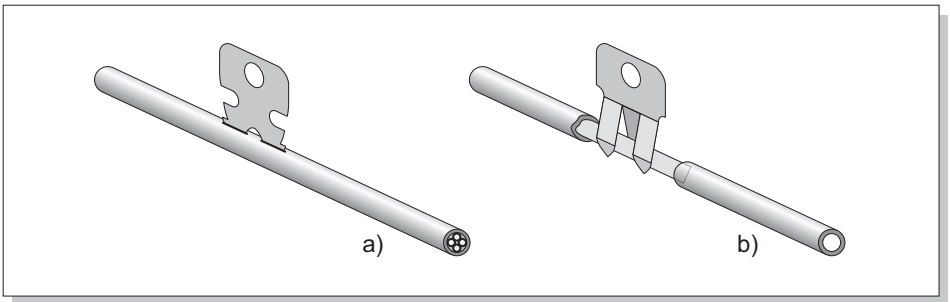

Figure 6.18 Crimping solid and stranded wire cables

Cause (3): Short circuit in the cable due to kinks, excessive bending, defective material, or a nail inadvertently driven through the cable.

Gathering Information; Common Errors

As with coaxial cable, comprehensive information about the context of a problem with twisted-pair cable provides a detailed description of the symptoms and clues to possible causes. Questions to ask at this stage include:

- Has anyone connected or disconnected a PC (laptop or desktop) or any other component to or from the network?
- Has anyone installed an interface card in a computer?
- Has a telephone or fax machine been installed?
- Has anyone stepped on a cable?
- Has any maintenance work been performed in the building recently (by a telephone company or building maintenance personnel, for example)?
- Has anyone (including cleaning personnel) moved any equipment or furniture?

Figure 6.19 lists the most common causes of problems in twisted-pair cabling infrastructures:

- Wiring errors in patch panels
- Wiring errors in connectors
- Crosstalk due to split pairs
- Near-end crosstalk due to inferior cable unsuitable for high-speed data
- Continuity faults due to poor crimp connections in connectors
- Continuity faults due to bends, kinks, loose connectors
- Short circuits due to mechanical stress or material defects
- Near-end crosstalk due to faulty installation of patch panels or cable routing
- Near-end crosstalk due to untwisted patching (in patch panels or TCUs)
- Impedance anomalies due to cramped cable bundles
- Excessive attenuation because cables are too long
- Electromagnetic interference (elevators, electric machinery) or mechanical stress (doors, furniture)

Figure 6.19 The most common causes of problems in twisted-pair cabling infrastructures

6.3 Fiber-Optic Cable

6.3.1 Fiber-Optic Cable: Specification and Implementation

In recent years fiber-optic cabling has proven to be a sturdy, high-performance transmission medium for use in both primary (campus) and secondary (building or vertical) cabling. The fiber-optic cables most commonly used are multimode cables with wavelengths of 850 nm or 1,300 nm. At power levels of -10 dBm to -20 dBm, signals can travel distances of some 5 kilometers. The dynamic range of such segments is between 15 dB and 20 dB. With the trend toward data speeds of 622 Mbit/s and 2.4 Gbit/s, however, even LAN infrastructures are increasingly coming to rely on single-mode, fiber-optic cabling with a wavelength of 1,550 nm.

Two types of connectors are used in fiber-optic LANs: those that make contact between one fiber and the next fiber (mated connections), and those that leave an air gap between the fiber end and the connector (unmated connections). Unmated connections are easier to work with because they are not as easily contaminated as mated connections, but they have a higher insertion loss.

Figure 6.20 lists the types of fiber-optic cabling and connection systems used in various LAN topologies.

LAN topologies:	Ethernet FOIRL	10Base-F	Token Bus	Token Ring	FDDI (multimode)	FDDI (single-mode)	Fibre Channel	Gigabit Ethernet
Wavelength (nm)	850 (790 – 910)	850 800 – 910 (active) 820 – 910 (passive)	850 800 – 910	850 800 – 910	1300 (1270 – 1380)	1300 (1270 - 1340, Cat. 1) (1290 - 1330, Cat. 2)	1300	850 (multimode) 13,000 (single-mode)
Signal power (dBm)	-12 to -15	-12 to -20 (active) -11 to -15 (passive)	-7 to -11	-13 to -22	-14 to -20	-14 to -20 (Cat. 1) -15 to -37 (Cat. 2)		
Receiver sensitivity (dBm)	- 9 to -27	-12 to -32.5 (active) - 27 to -41 (passive)	-31/41 to -11/-21	-12 to -30	-14 to -31	-14 to -31 (Cat. 1) -15 to -37 (Cat. 2)		
Maximum network length (km)	4.5	4.5	4.5	4.5	200	200		
Maximum segment length (km)	1	2	1	2	2	2	1 (200 Mbit/s) >10 (800 Mbit/s)	0.55 (multimode 5 single-mode)
Connector types	F-SMA, ST	ST, F-SMA	MIC; ST; Biconic, F-SMA, Mini-BNC	MIC; ST; Biconic, F-SMA, Mini-BNC	MIC, ST	SM-MIC	SC	SC

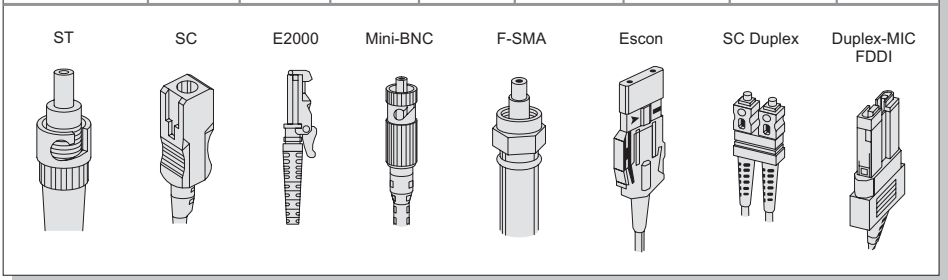

Figure 6.20 Fiber-optic cabling and connectors in local-area networks

The permissible length for a fiber-optic cable is derived from the available attenuation budget, which in turn depends on the performance of the transmitting device and the sensitivity of the receiver. Each splice in a cable increases the attenuation by about 0.1 dB; each connector by up to 0.5 dB.

6.3.2 Troubleshooting Fiber-Optic Cable

The most important tasks in diagnosing problems with fiber-optic cable involve checking the power and attenuation, and taking measurements with an optical time-domain reflectometer (OTDR).

Attenuation is measured in order to determine whether or not the total attenuation of a cable segment exceeds the attenuation budget. The first step is to set

up the testing conditions in accordance with IEC 874-1, Method 6. This involves inserting a reference cable in place of the cable segment to be tested, between the transmitter and receiver of the measuring instrument. A reference measurement is taken from this cable and compared with the results measured on the actual network cable. The reference values serve to offset the influence of the test location and the test connector. Once the reference values have been recorded, the same measurements are performed on the cable to be tested (see Figure 6.21).

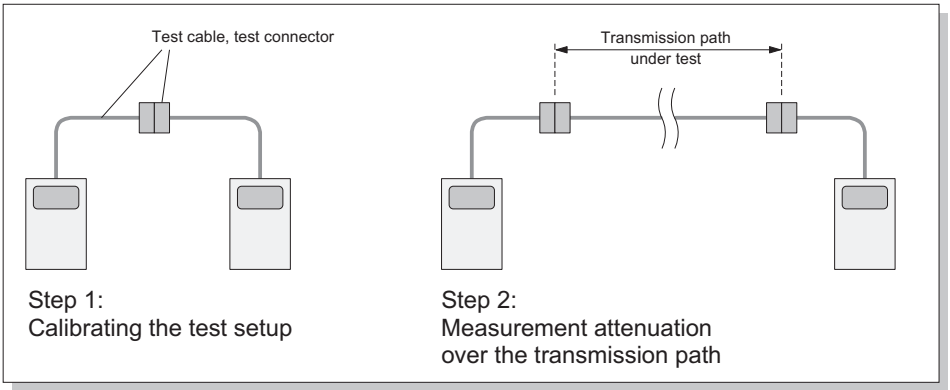

Figure 6.21 Attenuation measurement with test setup calibration in accordance with IEC 874-1

OTDR measurements are used to detect individual components of the overall attenuation along a segment of fiber-optic cable, and to precisely locate each component. When performing OTDR measurements, keep in mind that most OTDR devices have a "dead zone" at close range. The dead zone is the range that cannot be reliably evaluated due to reflections in the device connector and an overdriven OTDR. The sensitivity of the OTDR determines the maximum amplitude difference that the testing device can detect between the signal pulse and the reflected signal. Over longer cable segments, a higher dynamic means the ability to measure greater distances. With the relatively short distances found in LANs, high dynamics are also an advantage because they allow the use of shorter pulses, resulting in higher resolution. The shorter the signal pulse, the easier it is to detect separate reflections that arrive in rapid succession.

Regular maintenance of fiber-optic cables is also important. Cable maintenance tasks include regular measurements of the signal strengths of all active components, as well as checking the connector contacts for crossed fibers and contamination.

6.3.3 Symptoms and Causes: Fiber-Optic Cable

Symptom: No Connection

Cause: Line break due to external shock or extreme bending in the cable
The bending radius of the cable must not be less than 20 times the cable diameter. Thus for internal fiber-optic cables with a diameter of 3 mm, for example, the minimum bending radius allowed is 6 cm. Check all bend radii; if necessary, switch to an intact pair for the connection in question.
Use an OTDR to check for breaks in the cable. If no suitable test device is available, the "lighter test" can be used for cable segments of up to several hundred meters: hold a lighter to the cross section of the fiber at one end and verify that light is visible with the naked eye at other end.

Symptom: No Connection or Intermittent Connection Problems

Cause (1): Attenuation too high due to poor workmanship on splices or too many splices.
Check the signal strength using an optical source and power meter.
Cause (2): Contamination of connectors (dust, fingerprints, humidity, etc.)
Cause (3): Transmitter signal strength too low.
Increase light power or replace the LED/laser module.

Symptom: No Connection After New Installation

Cause (1): Faulty connection in wiring closet.
Cause (2): Poor splice; attenuation too high.
Cause (3): Dirty connectors (dust, fingerprints, humidity, etc.).

Gathering Information; Common Errors

As with copper cables, comprehensive information about the context of a problem with fiber-optic cable provides a detailed description of the symptoms and clues to possible causes. Questions to ask at this stage include:

- Has anyone connected or disconnected a PC (laptop or desktop) or any other component to or from the network?
- Has anyone installed an interface card in a computer?
- Has anyone stepped on a cable?
- Has any maintenance work been performed in the building recently (by a telephone company or building maintenance personnel, for example)?
- Has anyone (including cleaning personnel) moved any equipment or furniture?

The most common causes of problems in fiber-optic cabling infrastructures are listed here:

- Excessive loss due to faulty splices or connectors; too many splices or connectors
- Fiber break due to mechanical stress or insufficient bending radius
- Wrong fiber connected in splice tray or at patch panel
- Insufficient transmitter power
- Excessive loss due to contaminated connector
- Excessive loss due to excessive cable length

Figure 6.22 The most common causes of problems in fiber-optic cabling infrastructures

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